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United States Patent [19]

Ha et al.

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[45] **Date of Patent: Oct. 24, 2000**

[54] **ANTENNA APPARATUS FOR MOBILE TERMINAL**

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[73] Assignee: **Samsung Electronics Co., Ltd.**, Rep. of Korea

[21] Appl. No.: **09/258,932**

[22] Filed: **Mar. 1, 1999**

[30] **Foreign Application Priority Data**

Feb. 27, 1998 [KR] Rep. of Korea 98-6504

[51] **Int. Cl.**[7] **H01Q 1/24**

[52] **U.S. Cl.** **343/702**; 343/741; 343/866; 343/900

[58] **Field of Search** 343/702, 741, 343/742, 866, 867, 900, 901

[56] **References Cited**

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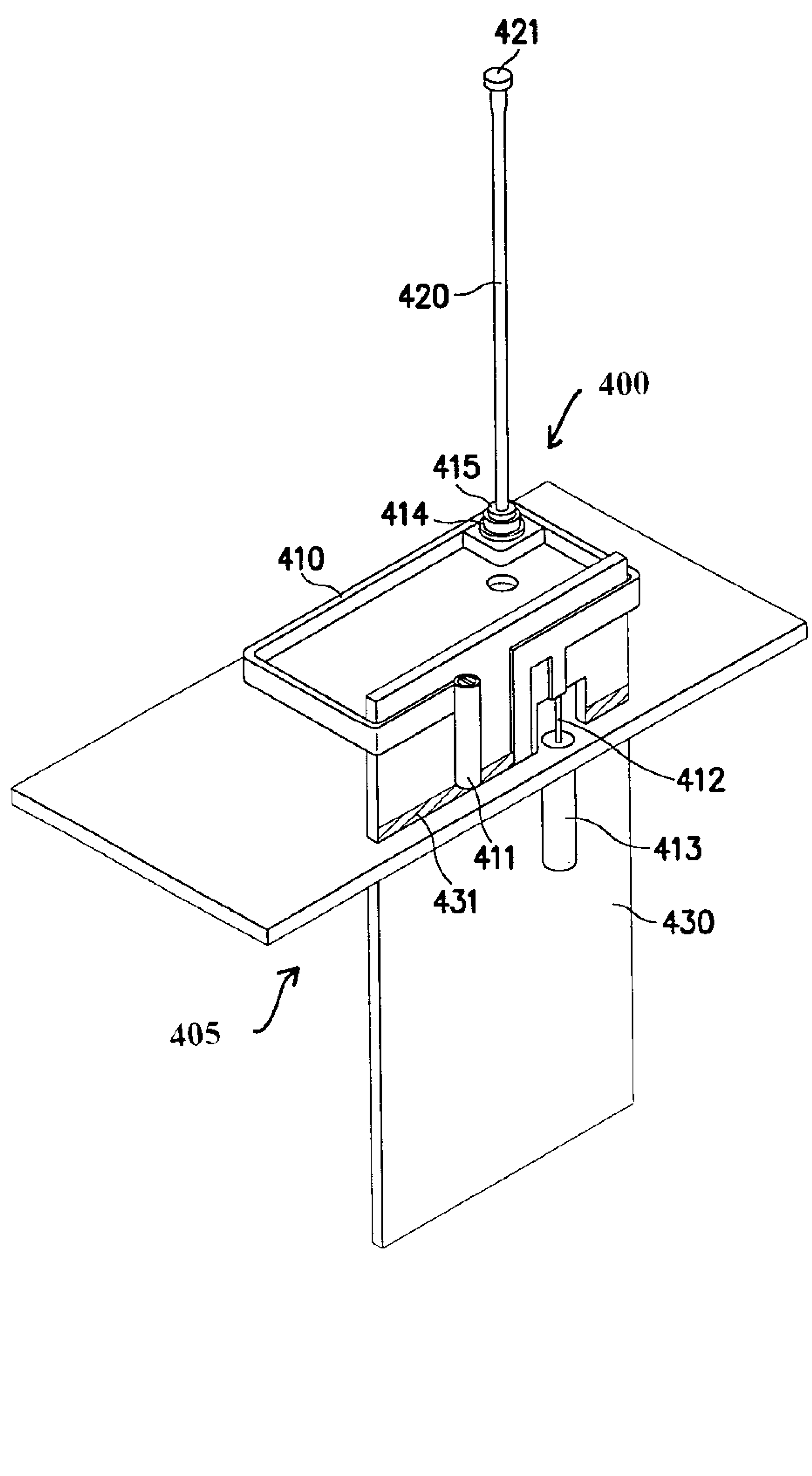
Primary Examiner—Tan Ho

Attorney, Agent, or Firm—Dilworth & Barrese

[57] **ABSTRACT**

An antenna apparatus for a mobile terminal is provided having a hula hoop antenna secured to a housing of the mobile terminal; a conductive line coupling the hula hoop antenna to a transceiver of the mobile terminal; a conductive fixing member having a through hole and contacting a portion of the hula hoop antenna; a cylindrical fixing member inserted into the through hole of the conductive fixing member; and a rod antenna extendable and retractable from and into the housing. The rod antenna is movable along a central axis of the cylindrical fixing member. The hula hoop antenna has a first end connected to a variable capacitor on a printed circuit board of the mobile terminal and a second end connected to a ground plate of the printed circuit board.

26 Claims, 16 Drawing Sheets



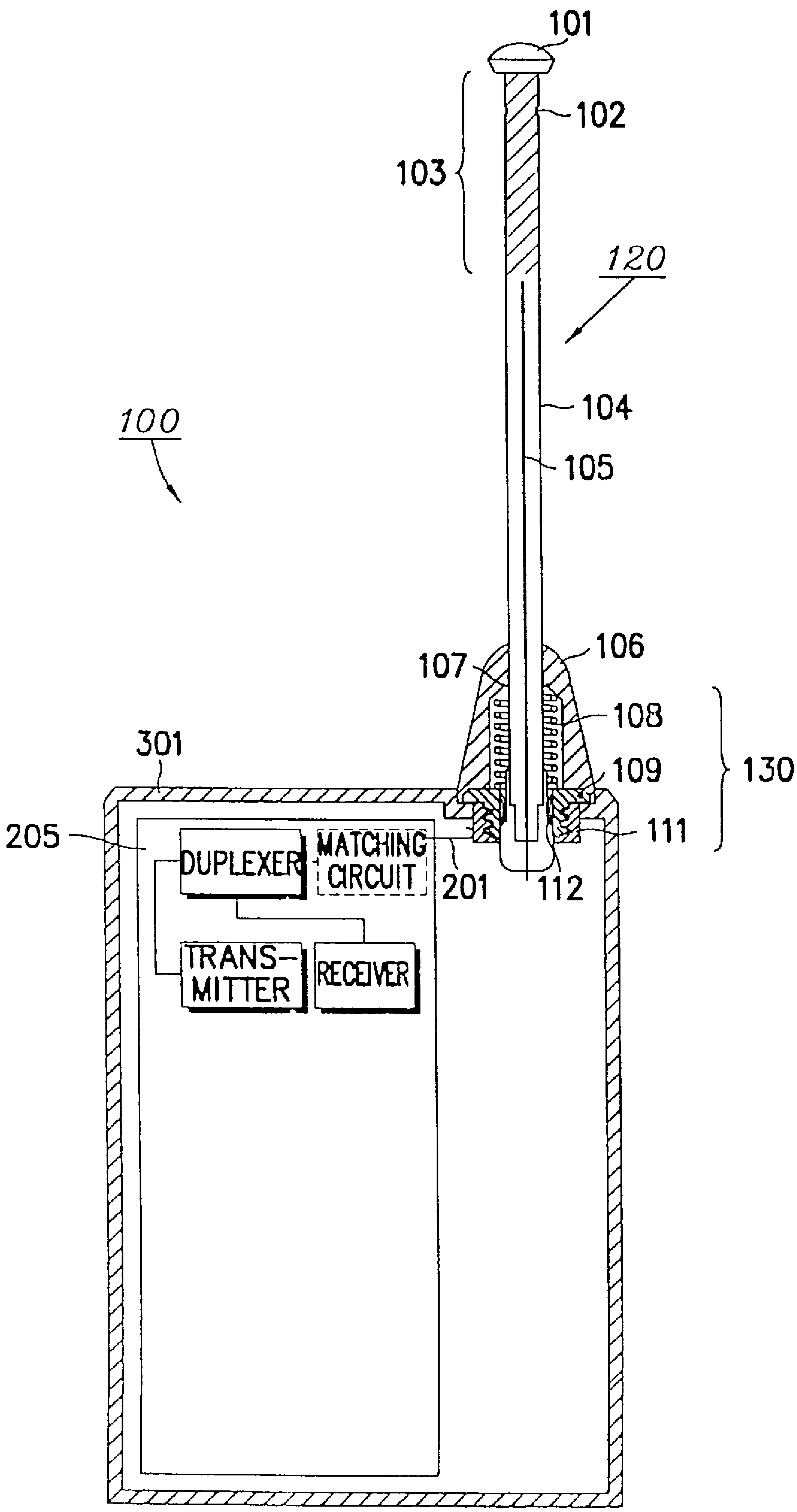


FIG. 1 (PRIOR ART)

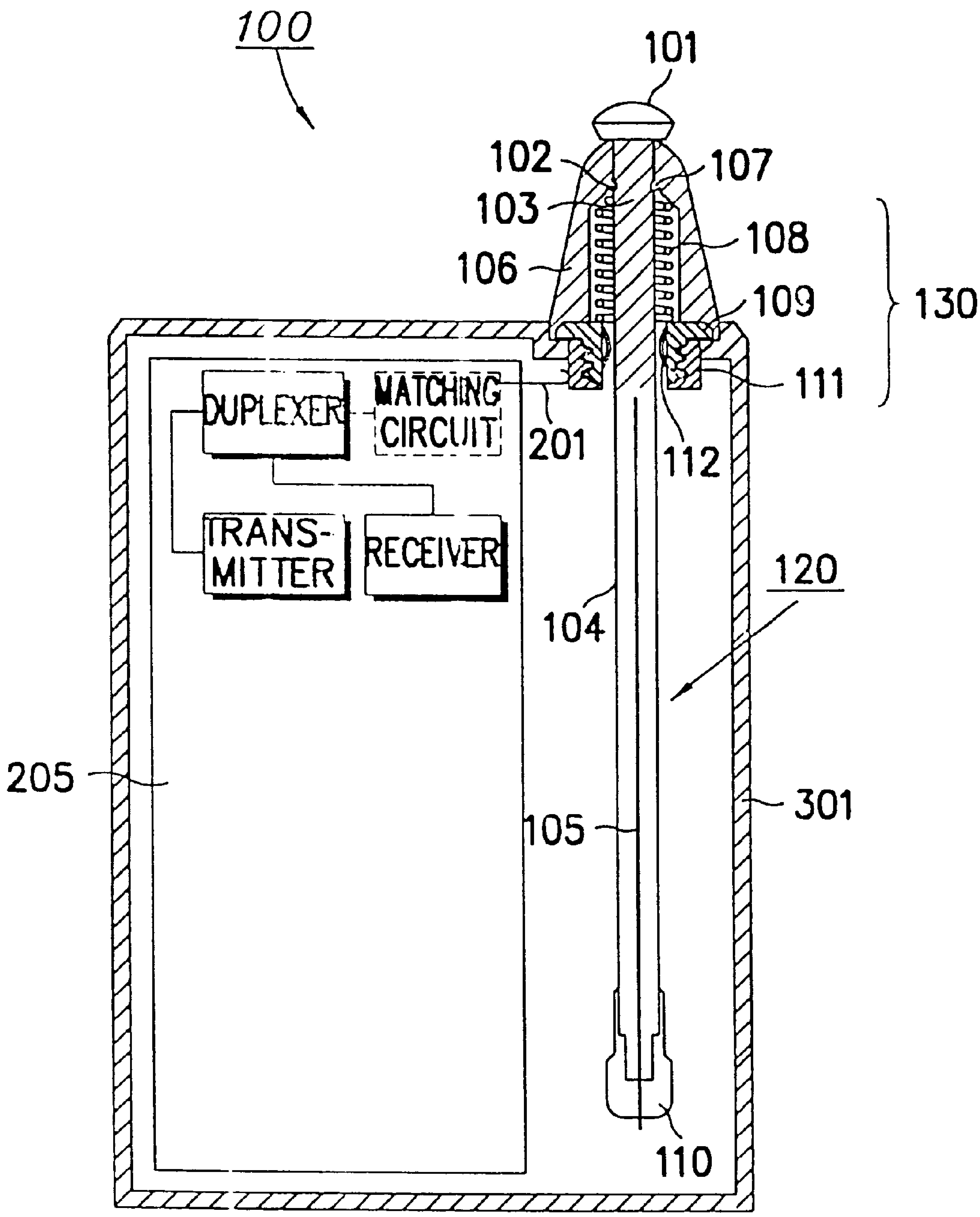


FIG. 2
(PRIOR ART)

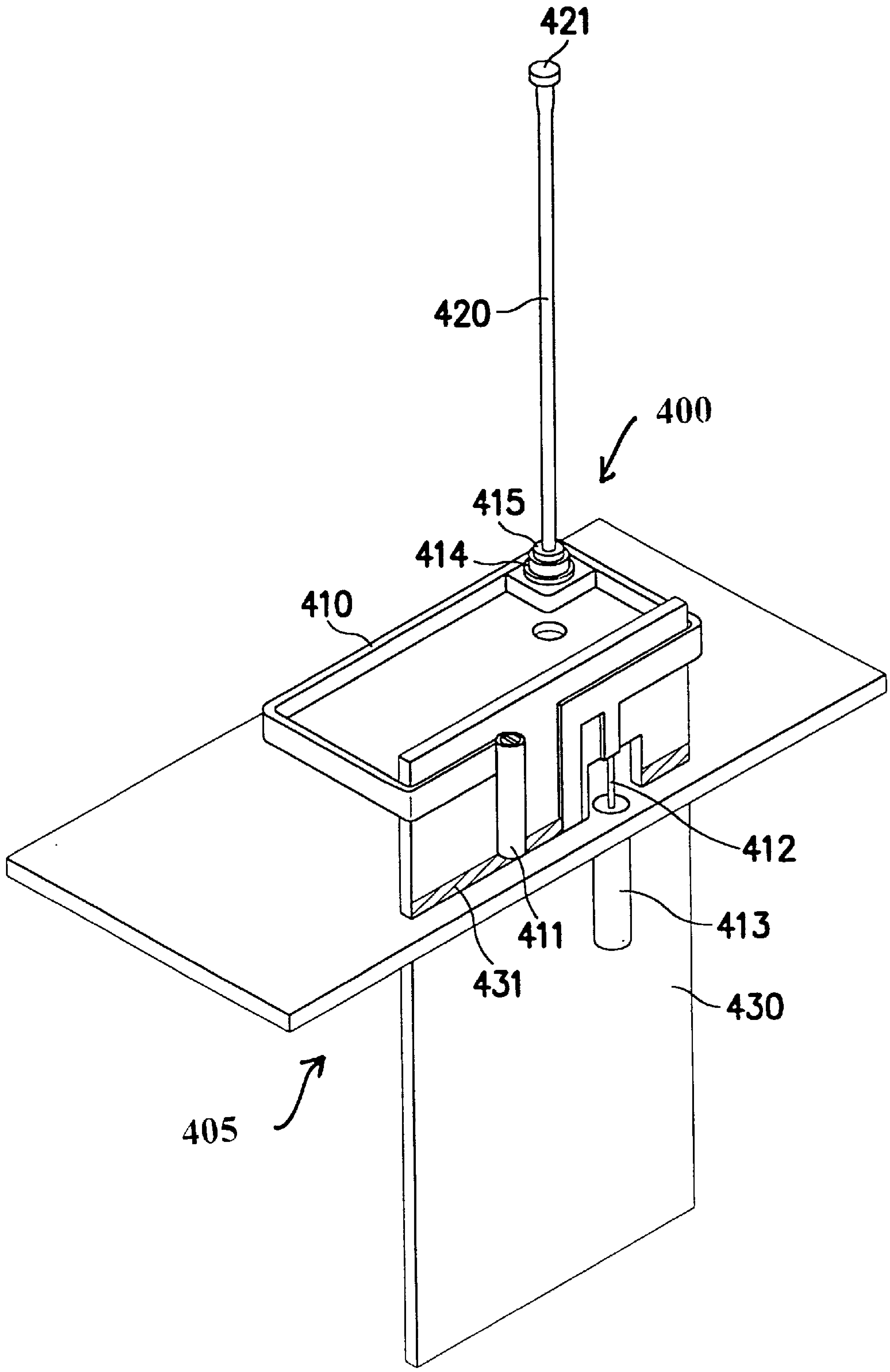


FIG. 3

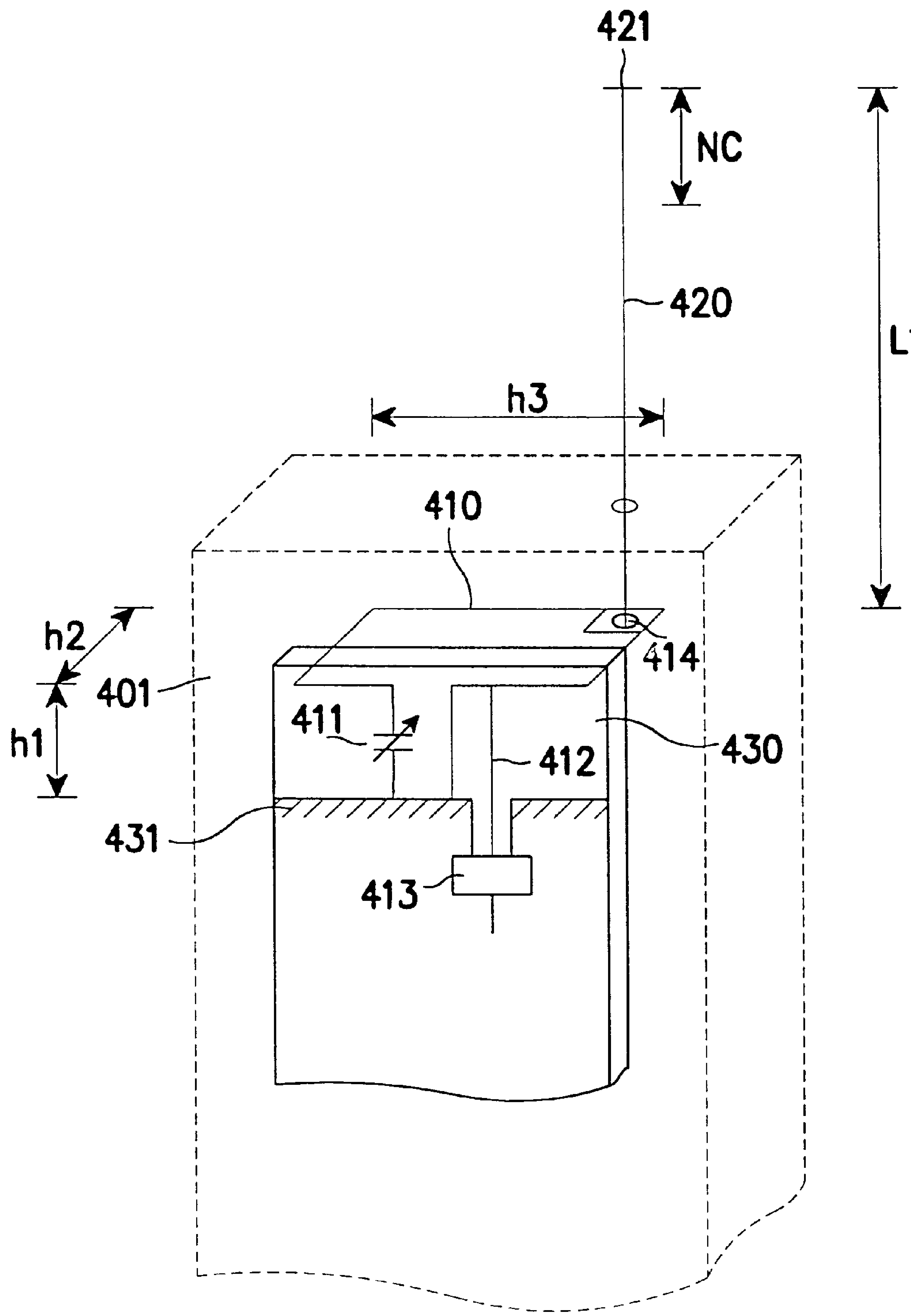


FIG. 4

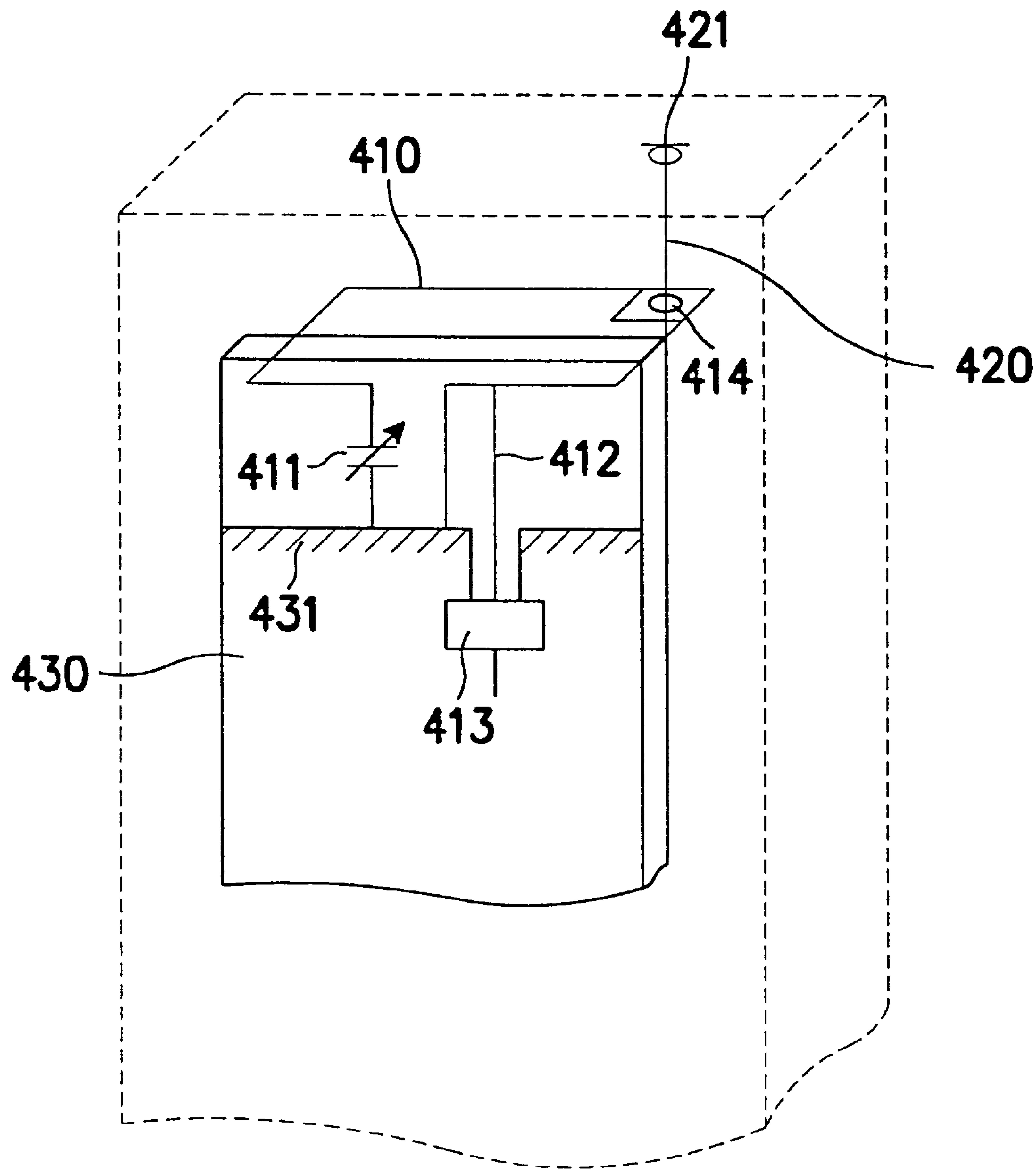


FIG. 5

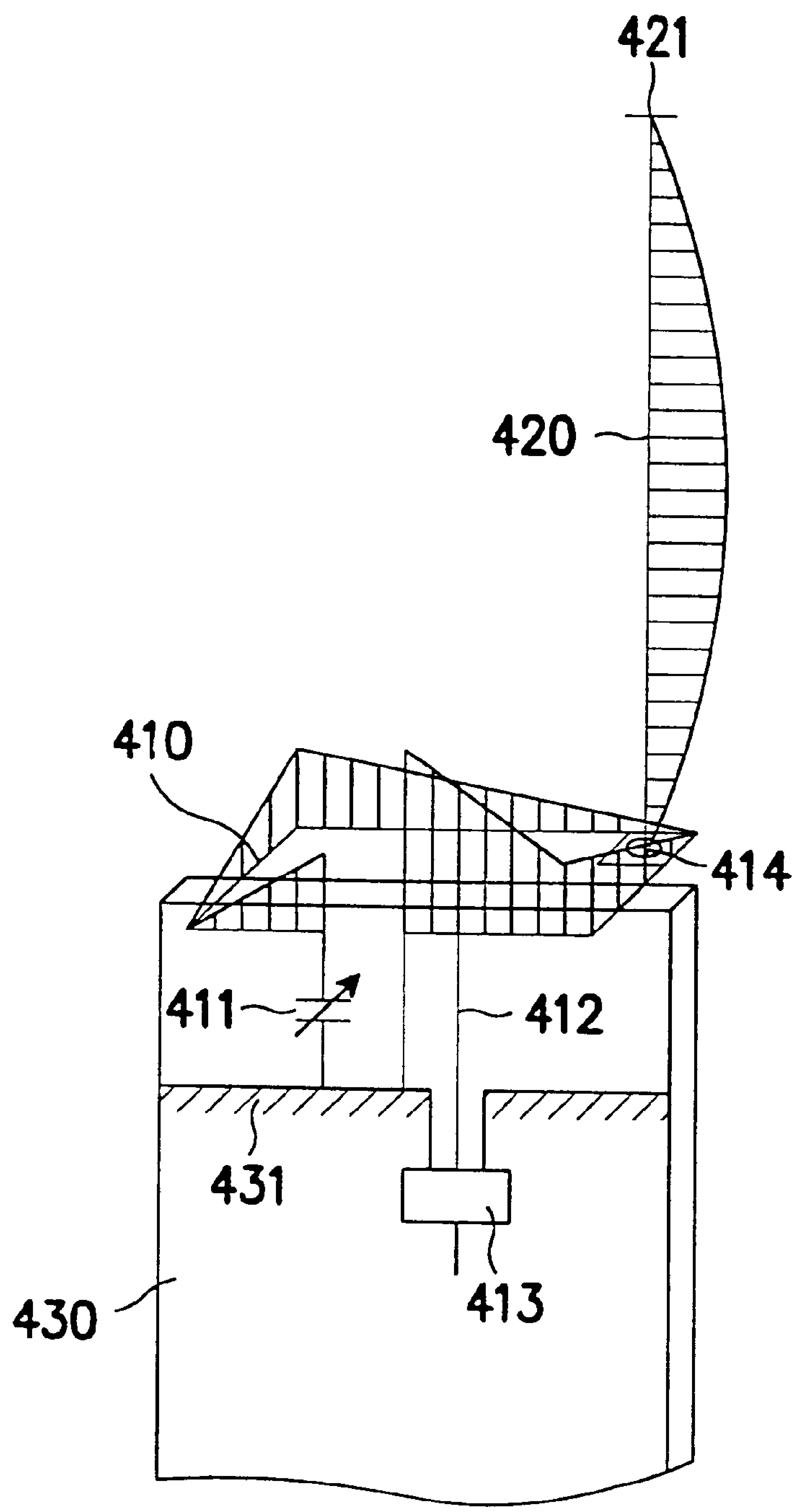


FIG. 6

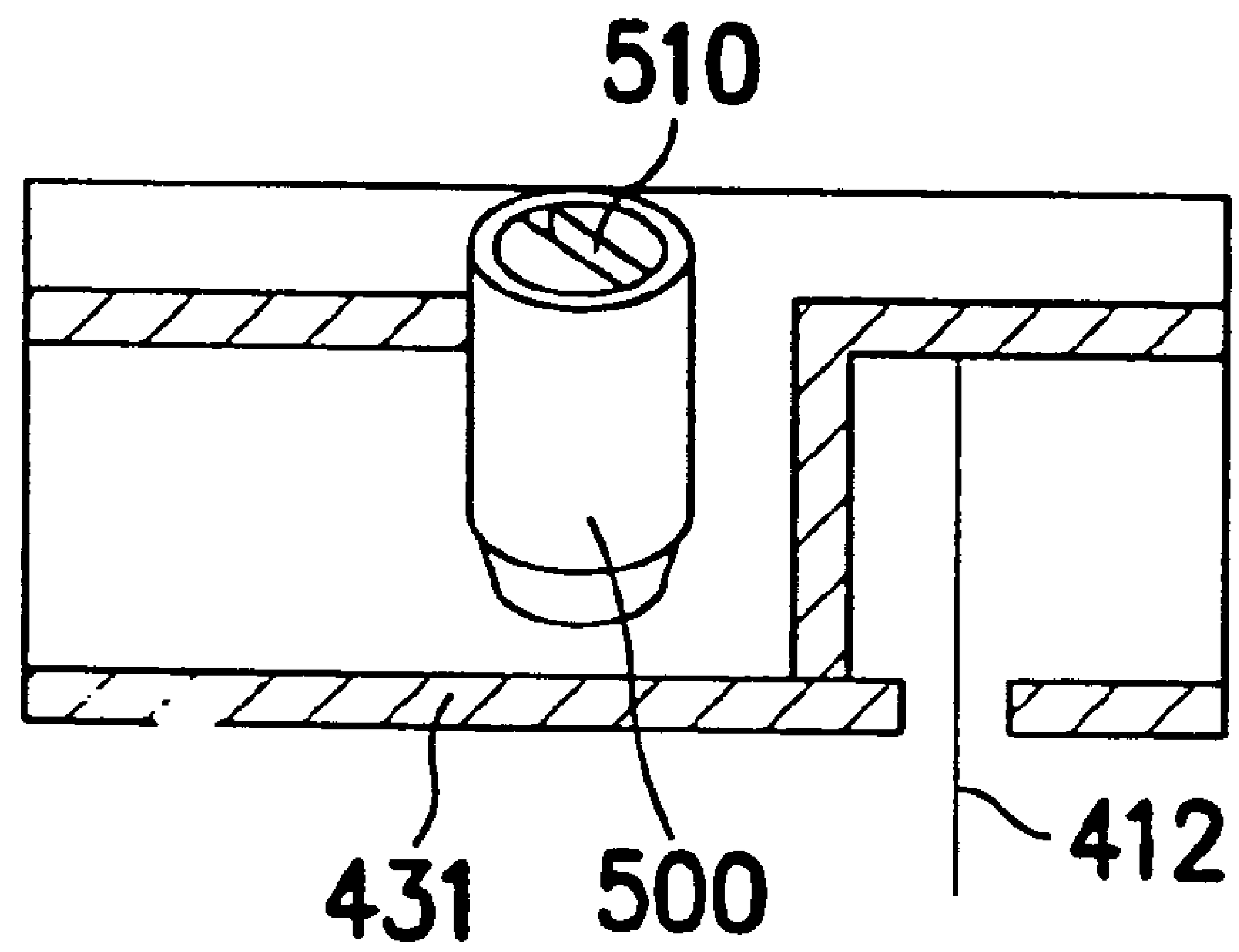


FIG. 7

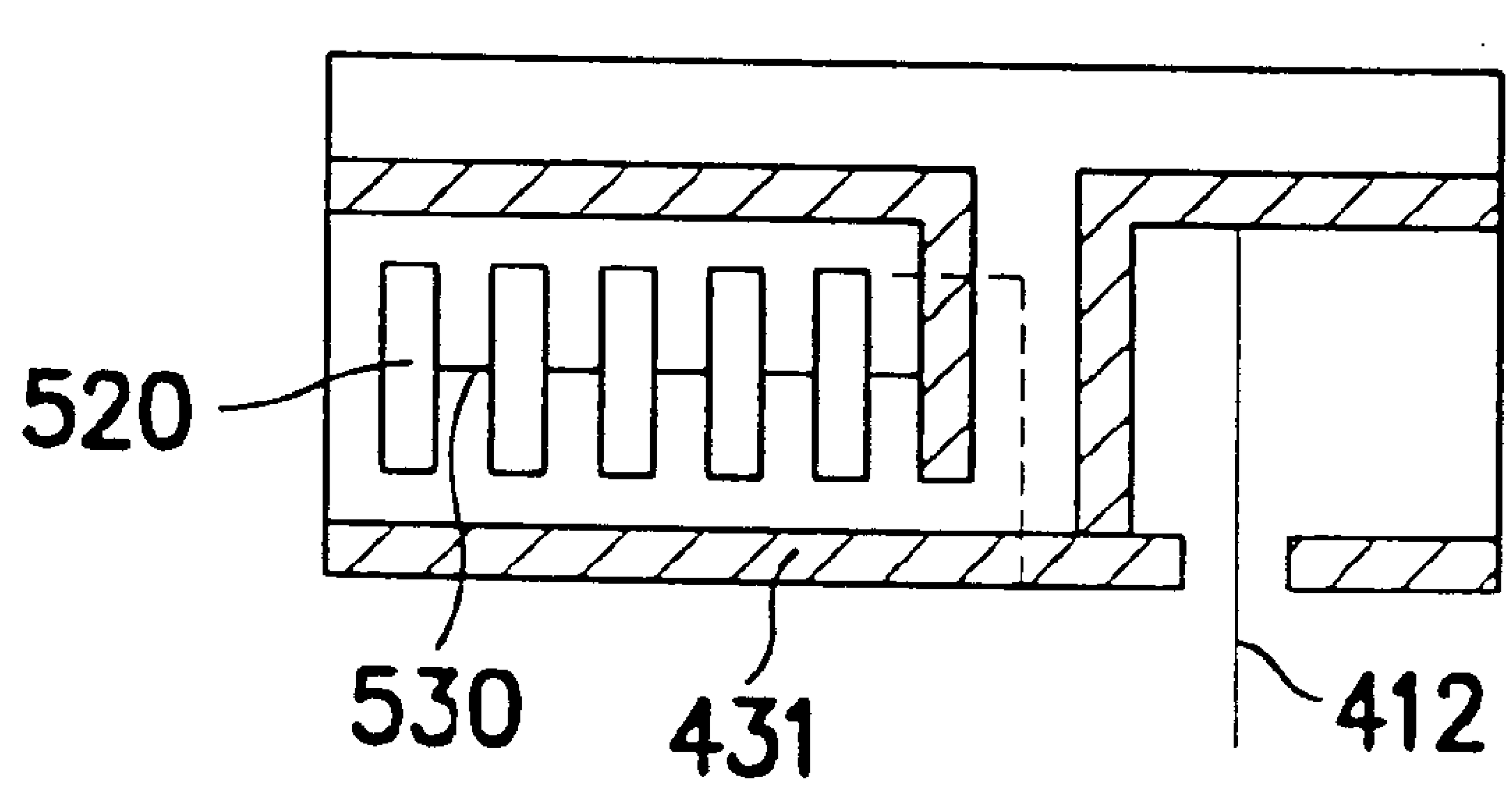
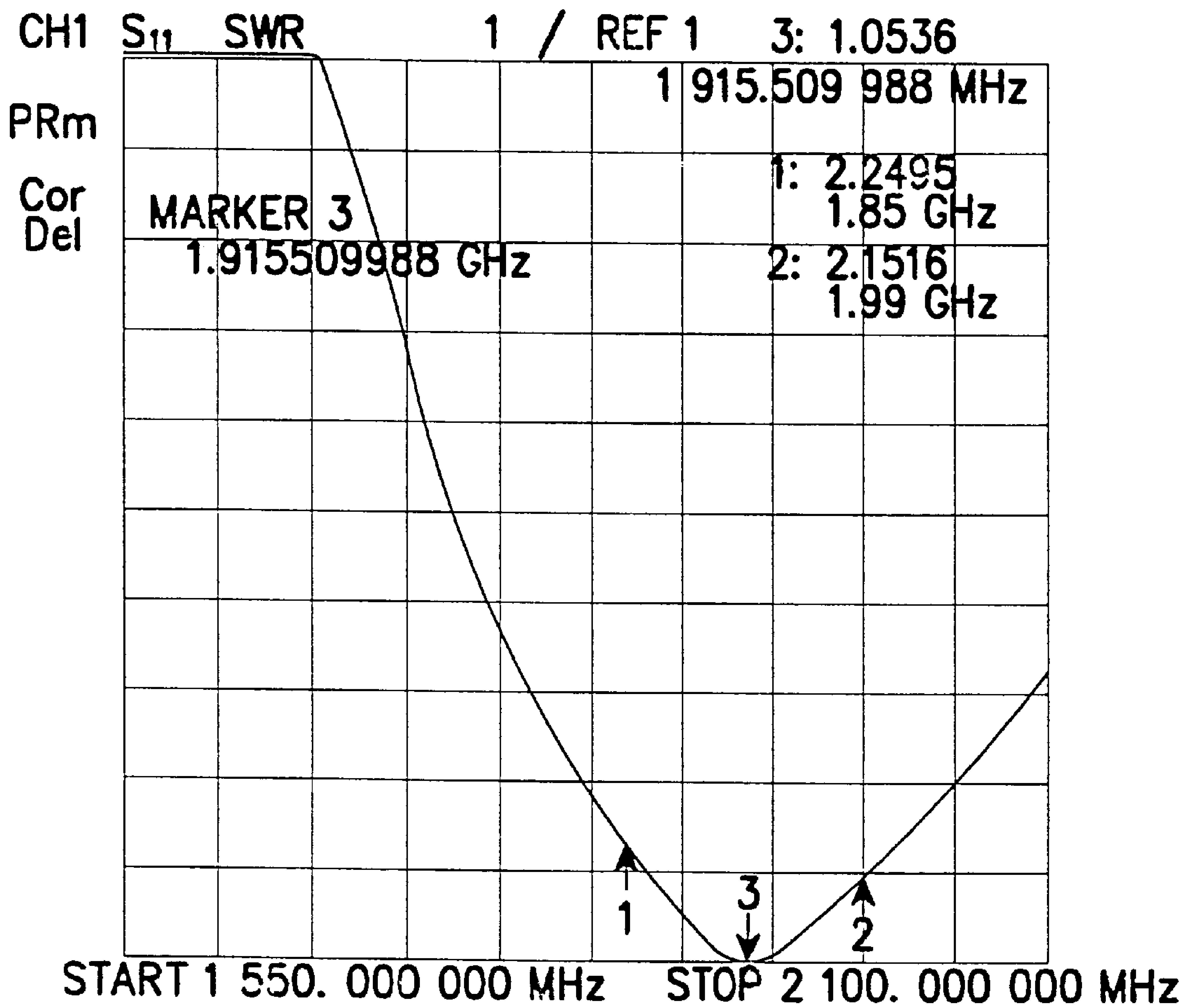


FIG. 8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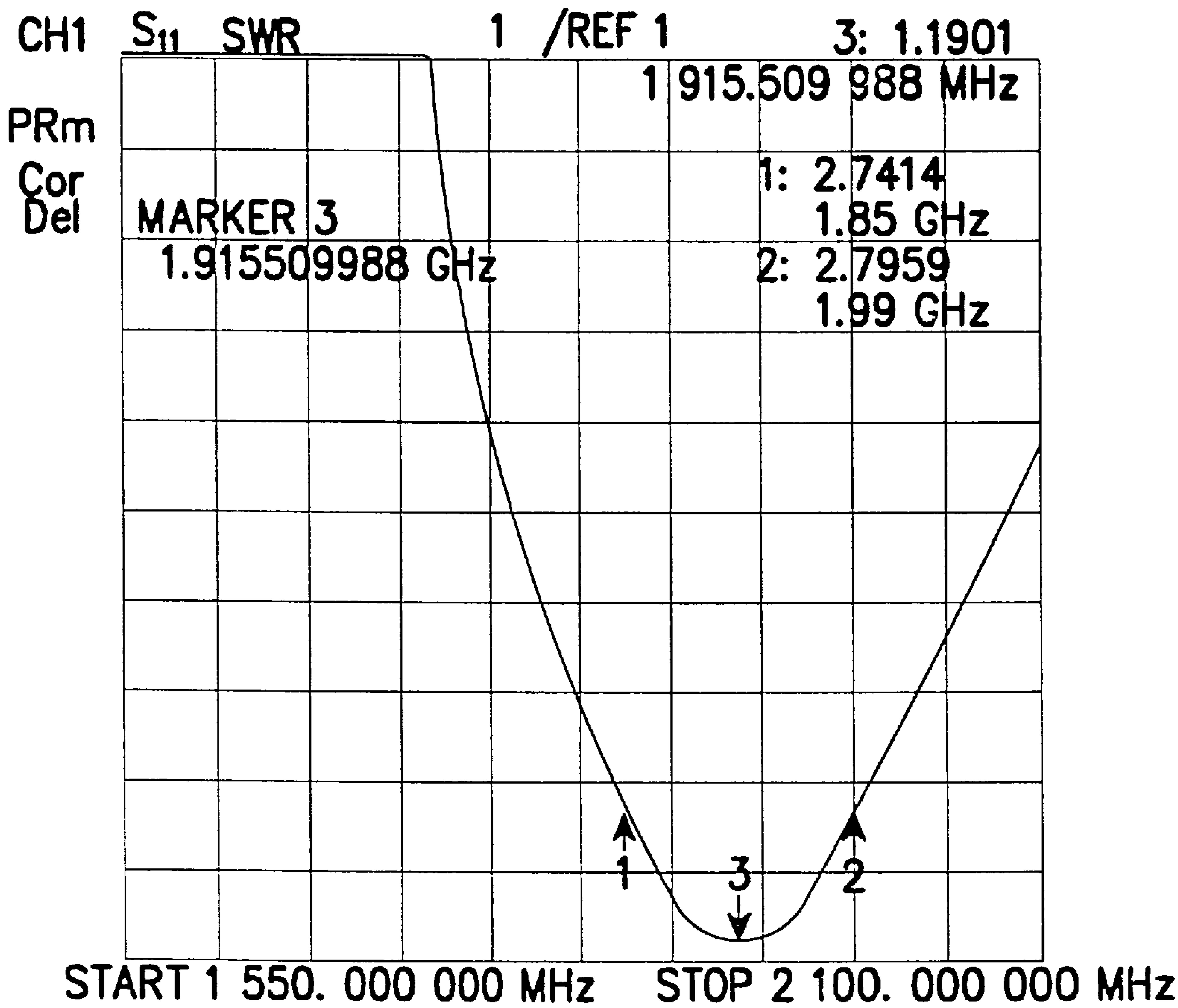
1 915.509 988 MHz
PRm
Cor
Del
MARKER 3
1.915509988 GHz
1: 2.2495
1.85 GHz
2: 2.1516
1.99 GHz
1
3
2
START 1 550. 000 000 MHz
STOP 2 100. 000 000 MHz

FIG. 9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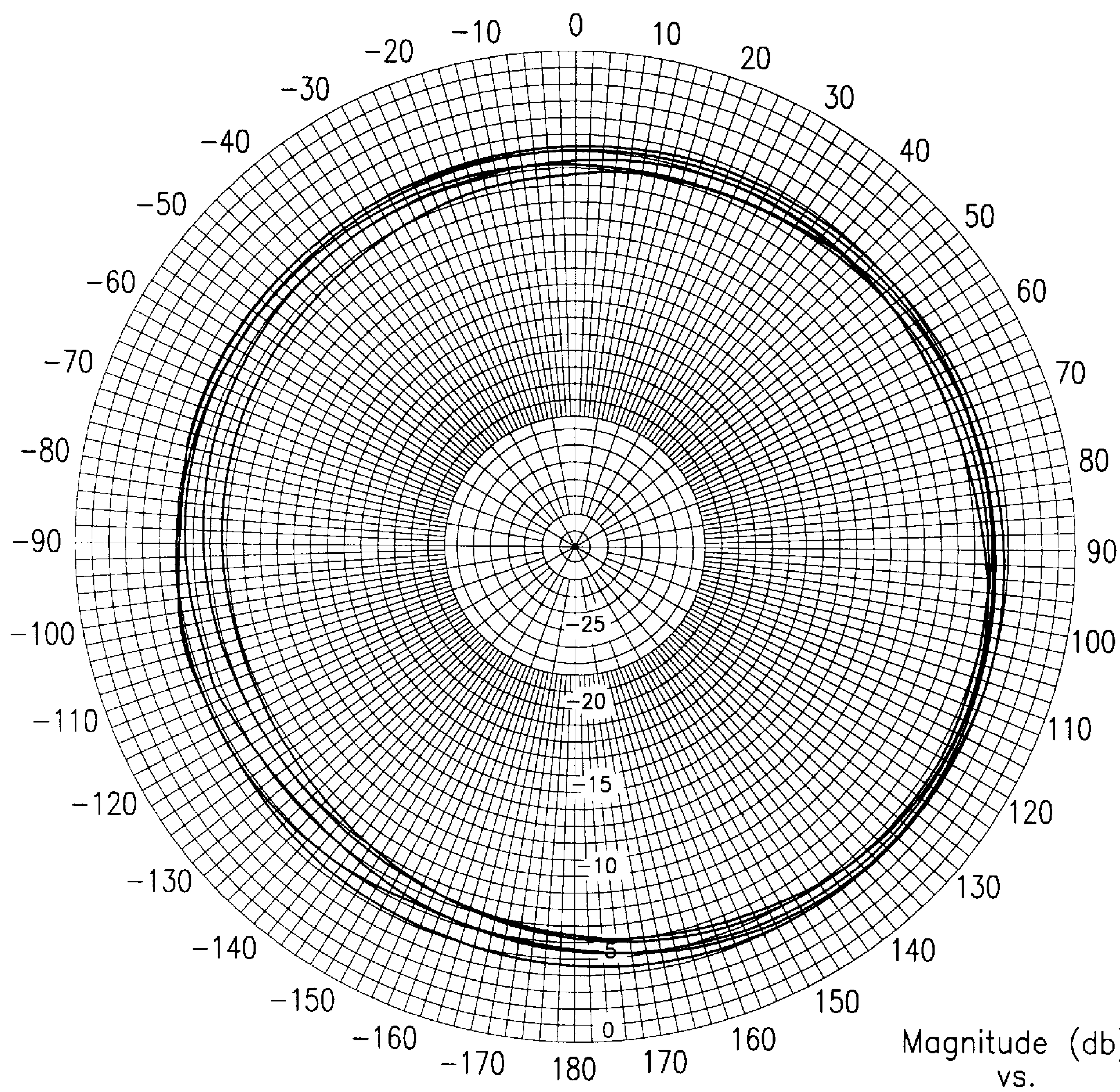
1 915.509 988 MHz
PRm
Cor
Del
MARKER 3
1.915509988 GHz
1: 2.7414
1.85 GHz
2: 2.7959
1.99 GHz
1
3
2
START 1 550. 000 000 MHz STOP 2 100. 000 000 MHz

FIG. 10

Retractable antenna on US PCS frequency
Azimuth plane, hula-hoop.
Ver. polarization, retracted position.

Tx pol: Horiz. Rx pol: Horiz.

Calibration status:
File: CALVHRN1.DAT
Chan.: 1710-1990M
Table: 1710-1990
Units: dBi

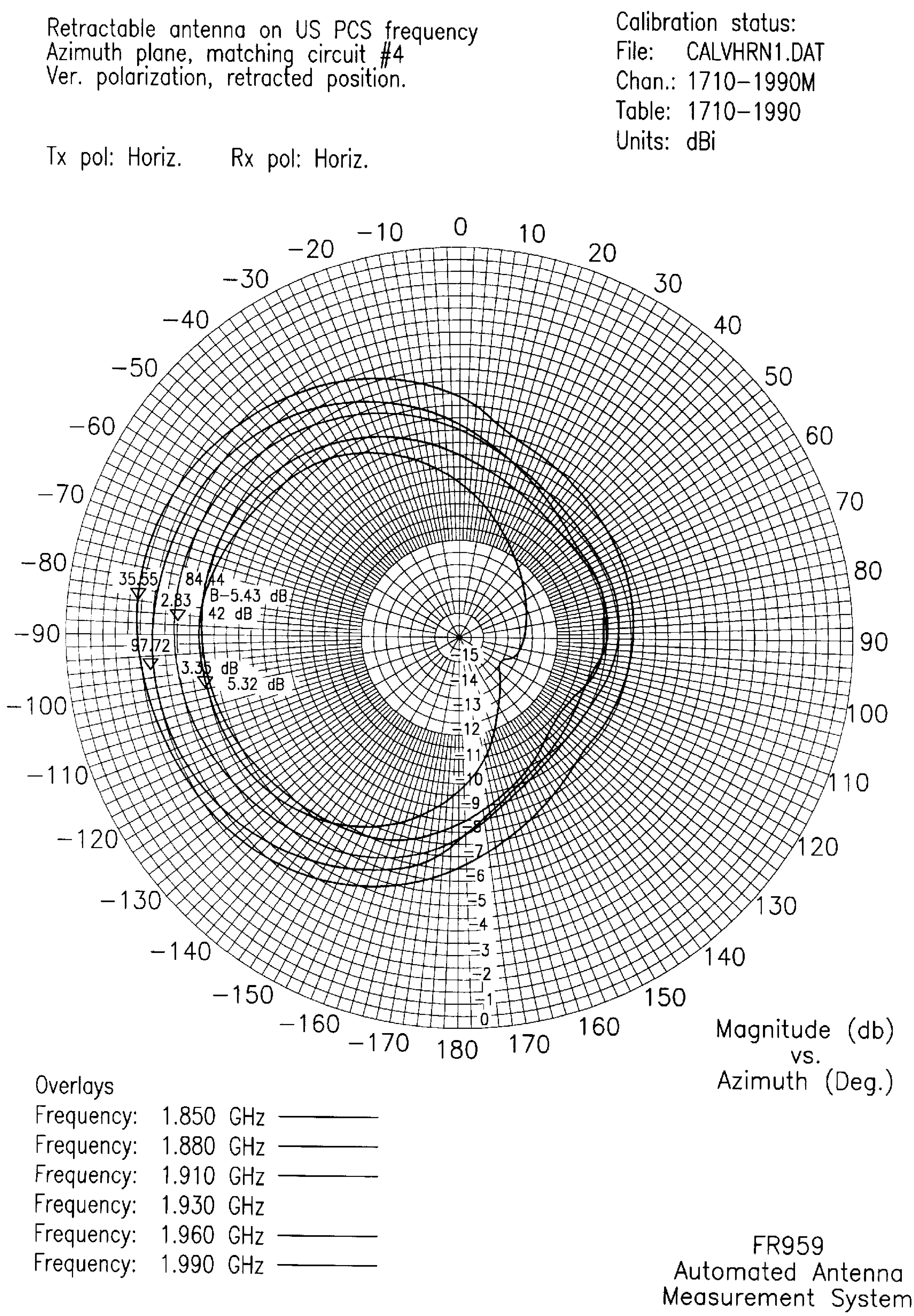


Magnitude (db)
vs.
Azimuth (Deg.)

Overlays
Frequency: 1.850 GHz
Frequency: 1.880 GHz
Frequency: 1.910 GHz
Frequency: 1.930 GHz
Frequency: 1.960 GHz
Frequency: 1.990 GHz

FR959
Automated Antenna
Measurement System

FIG. 11


Retractable antenna on US PCS frequency
Azimuth plane, matching circuit #4
Ver. polarization, retracted position.
Tx pol: Horiz. Rx pol: Horiz.
Calibration status:
File: CALVHRN1.DAT
Chan.: 1710–1990M
Table: 1710–1990
Units: dBi
Magnitude (db) vs. Azimuth (Deg.)
Overlays
Frequency: 1.850 GHz
Frequency: 1.880 GHz
Frequency: 1.910 GHz
Frequency: 1.930 GHz
Frequency: 1.960 GHz
Frequency: 1.990 GHz
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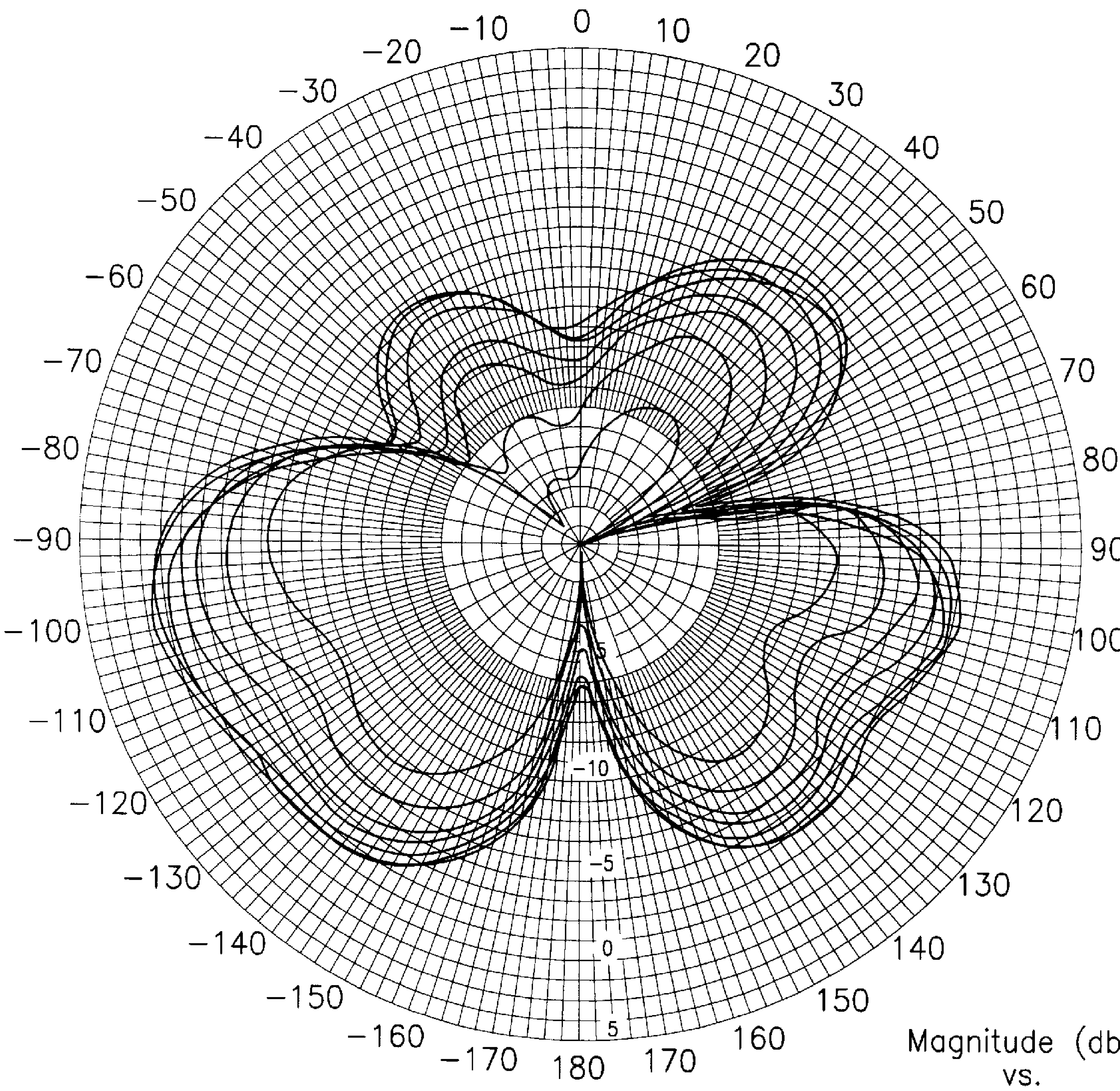
Automated Antenna
Measurement System

FIG. 12

Hula-hoop antenna (80mm handset)-Ret. poz.
Hor. pol, Elevation plane.(H)

Tx pol: Horiz. Rx pol: Horiz.

Calibration status:
File: CALHHRN1.DAT
Chan.: 1710-1990M
Table: 1710-1990
Units: dBi



Magnitude (db)
vs.
Azimuth (Deg.)

Overlays
Frequency: 1.750 GHz
Frequency: 1.805 GHz
Frequency: 1.850 GHz
Frequency: 1.870 GHz
Frequency: 1.890 GHz
Frequency: 1.910 GHz
Frequency: 1.960 GHz
Frequency: 1.990 GHz

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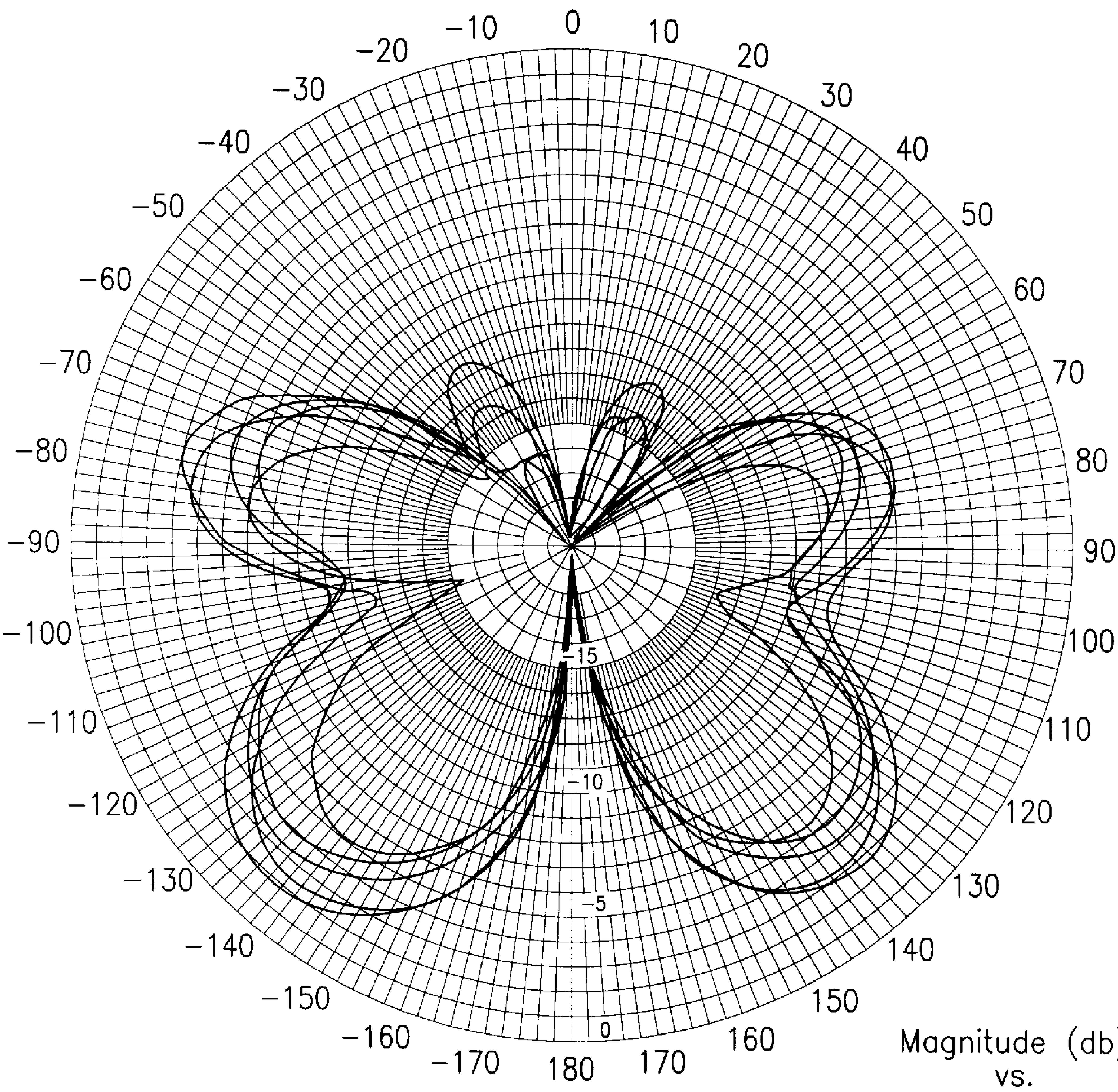
Automated Antenna
Measurement System

FIG. 13

Retractable antenna on US PCS frequency
Elevation plane, matching circuit #4
Hor. polarization, retracted position.

Tx pol: Horiz. Rx pol: Horiz.

Calibration status:
File: CALHHRN1.DAT
Chan.: 1710−1990M
Table: 1710−1990
Units: dBi



Magnitude (db)
vs.
Azimuth (Deg.)

Overlays
Frequency: 1.850 GHz
Frequency: 1.880 GHz
Frequency: 1.910 GHz
Frequency: 1.930 GHz
Frequency: 1.960 GHz
Frequency: 1.990 GHz

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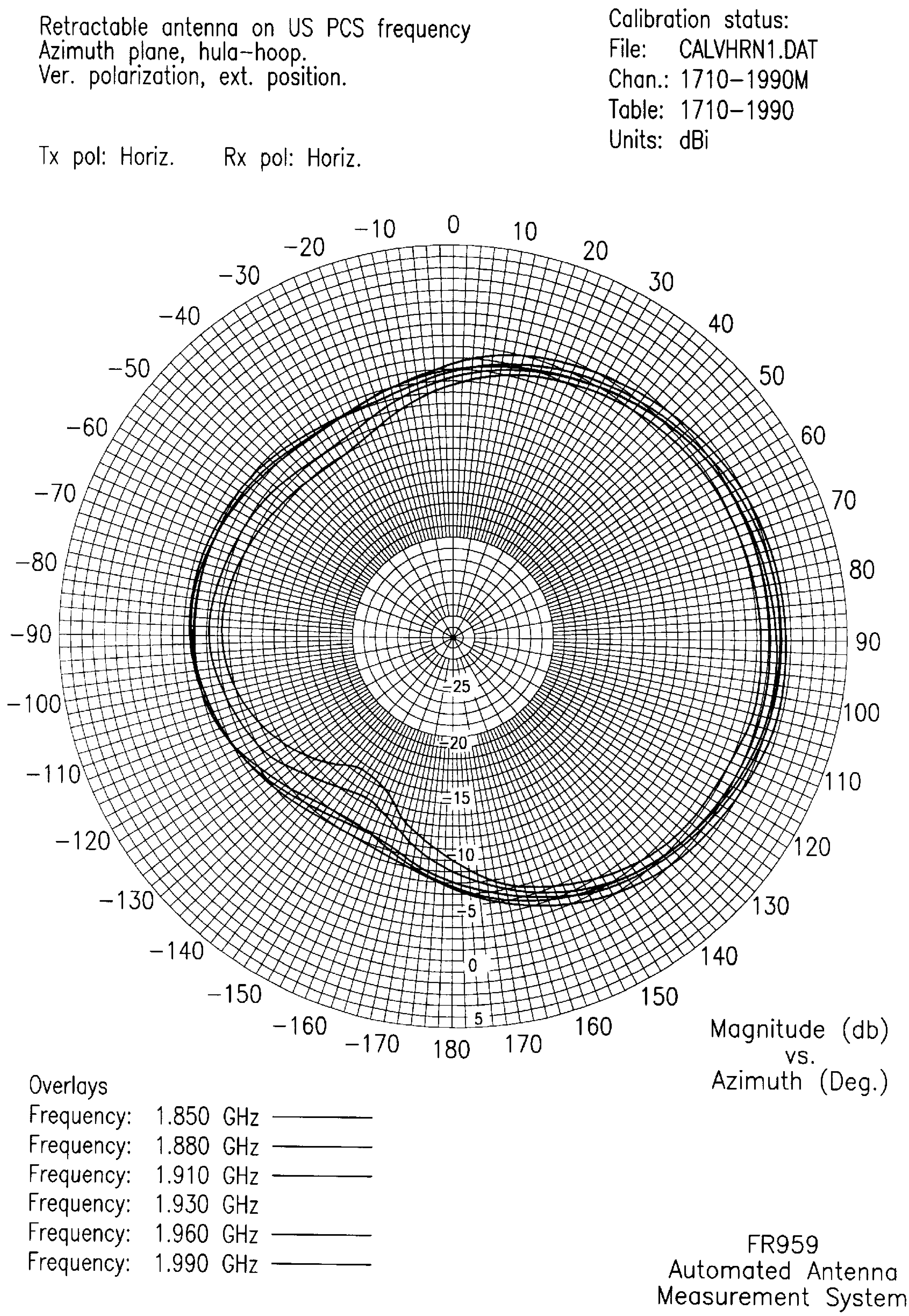
Measurement System

FIG. 14



Retractable antenna on US PCS frequency
Azimuth plane, hula-hoop.
Ver. polarization, ext. position.
Tx pol: Horiz. Rx pol: Horiz.
Calibration status:
File: CALVHRN1.DAT
Chan.: 1710-1990M
Table: 1710-1990
Units: dBi
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 -170 -160 -150 -140 -130 -120 -110 -100 -90 -80 -70 -60 -50 -40 -30 -20 -10
-25 -20 -15 -10 -5 0 5
Magnitude (db) vs. Azimuth (Deg.)
Overlays
Frequency: 1.850 GHz
Frequency: 1.880 GHz
Frequency: 1.910 GHz
Frequency: 1.930 GHz
Frequency: 1.960 GHz
Frequency: 1.990 GHz
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Automated Antenna
Measurement System

FIG. 15

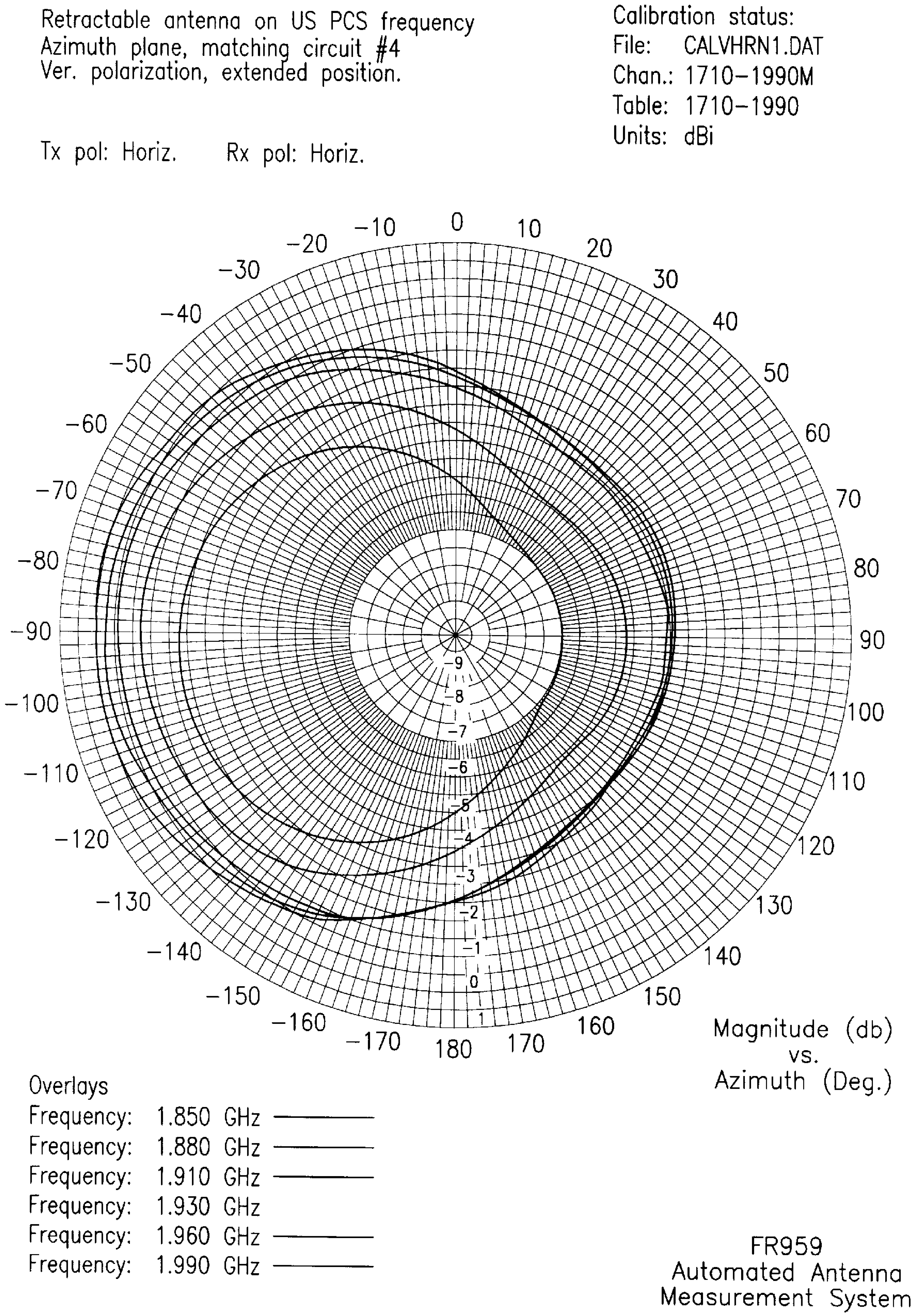
Retractable antenna on US PCS frequency
Azimuth plane, matching circuit #4
Ver. polarization, extended position.
Tx pol: Horiz. Rx pol: Horiz.
Calibration status:
File: CALVHRN1.DAT
Chan.: 1710-1990M
Table: 1710-1990
Units: dBi
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
-170
-160
-150
-140
-130
-120
-110
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Magnitude (db)
vs.
Azimuth (Deg.)
Overlays
Frequency: 1.850 GHz
Frequency: 1.880 GHz
Frequency: 1.910 GHz
Frequency: 1.930 GHz
Frequency: 1.960 GHz
Frequency: 1.990 GHz
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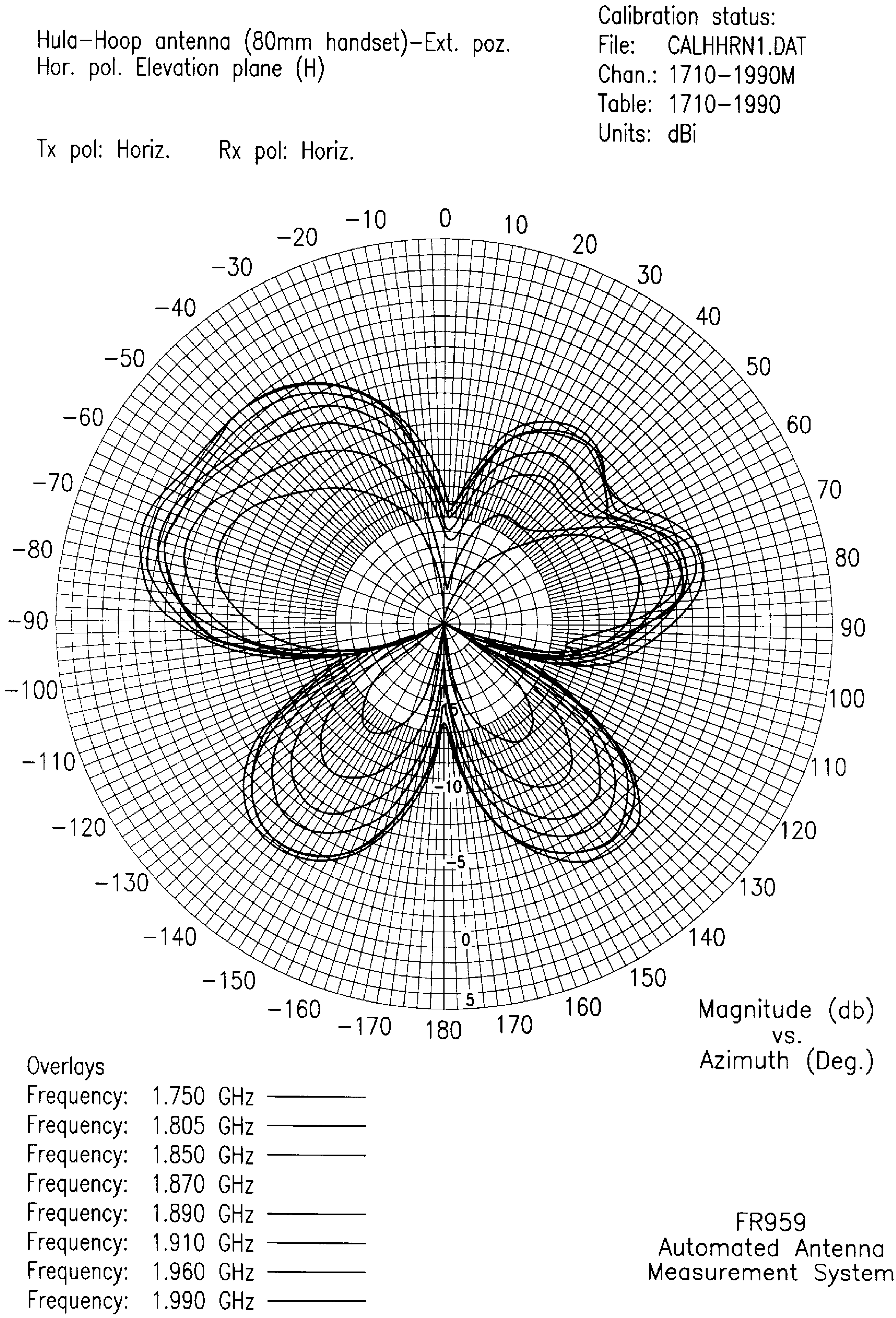
FIG. 16



Hula–Hoop antenna (80mm handset)–Ext. poz.
Hor. pol. Elevation plane (H)
Calibration status:
File: CALHHRN1.DAT
Chan.: 1710–1990M
Table: 1710–1990
Units: dBi
Tx pol: Horiz. Rx pol: Horiz.
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
–10
–20
–30
–40
–50
–60
–70
–80
–90
–100
–110
–120
–130
–140
–150
–160
–170
–10
–5
0
5
Magnitude (db)
vs.
Azimuth (Deg.)
Overlays
Frequency: 1.750 GHz
Frequency: 1.805 GHz
Frequency: 1.850 GHz
Frequency: 1.870 GHz
Frequency: 1.890 GHz
Frequency: 1.910 GHz
Frequency: 1.960 GHz
Frequency: 1.990 GHz
FR959
Automated Antenna
Measurement System

FIG. 17

ANTENNA APPARATUS FOR MOBILE TERMINAL

BACKGROUND

1. Field of the Invention

The present invention relates to an antenna apparatus for a mobile terminal and in particular, to an antenna apparatus for a mobile terminal where the antenna apparatus includes a hula hoop antenna and an extendable rod antenna for operating the antenna apparatus in an extended and in a retracted state.

2. Description of the Related Art

An antenna apparatus for a mobile terminal generally includes a fixed helical antenna and a retractable rod antenna. The helical antenna operates in a retracted state and the rod antenna operates in an extended state.

FIGS. **1** and **2** illustrate a prior art antenna apparatus having a rod antenna in the extended state and in the retracted state, respectively. A detailed discussion of the structure and operation of the antenna apparatus shown by FIGS. **1** and **2** can be found in Korean Patent Registration No. 107414/1996.

The antenna apparatus for a mobile terminal, as illustrated by FIGS. **1** and **2**, includes a helical antenna **130** mounted on an upper portion of a housing **301**, and a rod antenna **120** fixed to the housing **301** by an antenna cap **106**. The hollow antenna cap **106** has a protrusion **107** formed at an upper, inner wall through which the rod antenna **120** is inserted. Under the antenna cap **106**, a conductive female screw **111** is fixed to the upper end of the housing **301**. A cylindrical male screw **109** having a through hole is screwed to the female screw **111**. A head of the cylindrical male screw **109** is attached to a lower end of a helical winding **108** inserted into an opening of the antenna cap **106**. The antenna cap **106** is fixed to the housing **301** such that a lower end of the antenna cap **106** is fixed to the head of the cylindrical male screw **109**.

The rod antenna **120** is composed of a polyacetal rod **104**, an antenna core line **105** inserted into the polyacetal rod **104**, an isolation element **103** with a fixing groove **102** formed at an upper, outer circumference, and a pull **101** formed at an upper end of the isolation element **103**. The rod antenna **120** is inserted into the antenna cap **106**, passing along a central axis of the helical antenna **130** and the through hole of the cylindrical male screw **109**. A lower end of the polyacetal rod **104** is fixed to a stopper **110**.

In the retracted state of the rod antenna **120**, the protrusion **107** formed at the upper portion of the antenna cap **106** is inserted into the fixing groove **102** of the isolation element **103** so that the rod antenna **120** may not extend out of the antenna cap **106** by itself. In the extended state of the rod antenna **120**, the stopper **110** fixed to the lower end of the polyacetal rod **104** is stopped by a plate spring **112** mounted on the through hole of the cylindrical male screw **109**. The female screw **111** is connected to a printed circuit board (PCB) **205** via a feeding connector **201**.

With continued reference to FIGS. **1** and **2**, the antenna core line **105** extends from the stopper **110** to the lower end of the isolation element **103**. The polyacetal rod **104** has a good restoring force and serves as a protection rod for the antenna core line **105**. The antenna core line **105** may be made of a silver-plated cooper wire or piano wire, or a super-elastic nickel-titanium wire (i.e., shape-memory alloy wire) having a good restoring force. An electric length of the antenna core line **105** measures between $\lambda/4$ and $\lambda/2$ (i.e., approximately 87–174 mm at 860 MHz), taking into consideration the vertical length of the housing **301**. In practice, a physical length of the antenna core line **105** can be reduced to 132 mm by virtue of a dielectric constant indicative of the polyacetal rod **104**. When the vertical length of the housing **301** is very short, a telescoping antenna may be used for the rod antenna **120**.

The helical winding **108** of the helical antenna **130** is made of a silver-plated piano wire having a diameter of approximately 5.6 mm. An electric length of the helical winding **108** is related to the length of the antenna core line **105** of the rod antenna **120**. A physical length of the helical antenna **130** is relatively much shorter than that of the rod antenna **120**.

The antenna apparatus is positioned at one side of the mobile terminal, i.e., there is a positional asymmetry in the placement of the antenna apparatus with respect to the housing of the mobile terminal. In the extended state of the rod antenna **120**, the positional asymmetry of the antenna apparatus, specifically, the positional asymmetry of the helical antenna **130** is non-problematic, since in the extended state, the overall length of the antenna apparatus is increased. Therefore, the distribution of radiation and the quality of communication is typically not affected.

However, in the retracted state of the rod antenna **120**, the overall length of the antenna apparatus is reduced and only the helical antenna **130** radiates a radio signal. As a result, due to the positional asymmetry of the helical antenna **130**, a radiation pattern indicative of the radiated radio signals is distorted, i.e., the radiation pattern is asymmetrical, thereby reducing the distribution of radiation in one or more directions. Hence, a receiving sensitivity may depend on the position of the mobile terminal.

Further, an increase in the operating frequency requires an extension in the size of the mobile terminal with respect to the wavelength which accelerates the distortion of the radiation pattern, thereby presenting a difficulty in designing a compact mobile terminal. To counteract this phenomenon, the length of the antenna apparatus can be increased. However, an increase in the length of the antenna apparatus presents a difficulty in designing a compact mobile terminal.

Therefore, a needs exists to provide a non-directional antenna apparatus for a mobile terminal which has a stable receiving sensitivity in the elevation and azimuth planes without compromising the compactness of the mobile terminal.

Further, a need exists to provide an antenna apparatus for a mobile terminal which has a symmetric radiation pattern in the retracted and extended states.

SUMMARY

The present invention provides an antenna apparatus for a mobile terminal having a hula hoop antenna secured to a housing of the mobile terminal; a conductive line coupling the hula hoop antenna to a transceiver of the mobile terminal; a conductive fixing member having a through hole and contacting a portion of the hula hoop antenna; a cylindrical fixing member inserted into the through hole of the conductive fixing member; and a rod antenna extendable and retractable from and into the housing. The rod antenna is movable along a central axis of the cylindrical fixing member. The hula hoop antenna has a first end connected to a variable capacitor on a printed circuit board of the mobile terminal and a second end connected to a ground plate of the printed circuit board.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a prior art antenna apparatus in the extended state;

FIG. 2 illustrates the prior art antenna apparatus of FIG. 1 in the retracted state;

FIG. 3 illustrates an antenna apparatus for a mobile terminal in accordance with the present invention;

FIG. 4 illustrates the antenna apparatus of FIG. 3 in the extended state;

FIG. 5 illustrates the antenna apparatus of FIG. 3 in the retracted state;

FIG. 6 illustrates a current distribution of the antenna apparatus of FIG. 3 in the extended state;

FIG. 7 illustrates a variable capacitor according to a first embodiment for the antenna apparatus of FIG. 3;

FIG. 8 illustrates a variable capacitor according to a second embodiment for the antenna apparatus of FIG. 3;

FIG. 9 is a graph illustrating a voltage standing wave ratio (VSWR) of the antenna apparatus of FIG. 5 in the retracted state;

FIG. 10 is a graph illustrating a voltage standing wave ratio of the antenna apparatus of FIG. 4 in the extended state;

FIG. 11 is a graph illustrating a radiation pattern of the antenna apparatus of FIG. 5 in the retracted state;

FIG. 12 is a graph illustrating a radiation pattern of the prior art antenna apparatus of FIG. 2 in the retracted state;

FIG. 13 is a graph illustrating a radiation pattern on an elevation plane of the antenna apparatus of FIG. 5 in the retracted state;

FIG. 14 is a graph illustrating a radiation pattern on the elevation plane of the prior art antenna apparatus of FIG. 2 in the retracted state;

FIG. 15 is a graph illustrating a radiation pattern on the azimuth plane of the antenna apparatus of FIG. 4 in the extended state;

FIG. 16 is a graph illustrating a radiation pattern on the azimuth plane of the prior art antenna apparatus of FIG. 1 in the extended state; and

FIG. 17 is a graph illustrating a radiation pattern on the elevation plane of the antenna apparatus of FIG. 4 in the extended state.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

It is to be understood that in the following description of a preferred embodiment, specific details are set forth to provide a more thorough understanding of the present invention, notwithstanding that one skilled in the art may practice the invention without these specific details. It is to be further understood that in the accompanying drawings, similar reference numerals are used to denote elements having similar or equivalent constructions. In the following description, well known functions or constructions may not be described in detail since they would obscure the invention in unnecessary detail.

FIG. 3 illustrates an antenna apparatus for a mobile terminal in accordance with the present invention designated generally by reference numeral **400**. FIGS. 4 and 5 illustrate the antenna apparatus of FIG. 3 in the extended state and the retracted state, respectively.

With reference to FIGS. 3 to 5, the antenna apparatus **400** includes a rectangular hula hoop antenna **410** and a rod antenna **420**. The hula hoop antenna **410** is placed at an upper, inner center of a housing **401** of a mobile terminal **405**. The rod antenna **420**, which is retractable and extendable into and from the housing **401** to change the state of the antenna apparatus **400**, i.e., between the extended and retracted states, is disposed at a top right corner of the hula hoop antenna **410**. The hula hoop antenna **410** is supported by a printed circuit board (PCB) **430**.

The hula hoop antenna **410** has a first end connected to a variable capacitor **411** on the PCB **430** and a second end connected to a ground plate **431** of the PCB **430**. The ground plate is removed at the upper portion of the PCB **430**. A microstrip line **412** couples the hula hoop antenna **410** with a low noise amplifier (LNA) **413** of a transceiver (not shown). A conductive fixing member **414** having a through hole is fixed to a corner of the hula hoop antenna **410**. A cylindrical fixing member **415** is inserted into the through hole of the conductive fixing member **414**.

The rod antenna **420** is movably restricted to the housing **401** by the cylindrical fixing member **415**. The rod antenna **420** includes a polyacetal rod, an isolation element with a length NC, and a pull button **421**. The polyacetal rod has a conductive core line (not shown) formed along a central axis thereof. Lower ends of the conductive core line and the polyacetal rod are fixed to a stopper (not shown).

In the retracted state, a lower end of the rod antenna **420** reaches a retraction point (not shown) in the housing **401** as it passes through the cylindrical fixing member **415**. In the extended state, the pull button **421** of the rod antenna **420** reaches a maximum extension point with respect to the housing **401** as the stopper fixed to the lower end of the polyacetal rod is stopped by the cylindrical fixing member **415**.

The rod antenna **420** is manufactured from a metal wire and has a length L1, thereby emulating a $\lambda/2$ antenna in the extended state. The hula hoop antenna **410** is manufactured from a metal strip or wire. The rod antenna **420** is coated with a nonconductive material to prevent it from electrically coupling with the hula hoop antenna **410** while in the retracted state. Further, the rod antenna **420** is thick in order to contact the hula hoop antenna **410** and to prevent the rod antenna **420** from being pulled out from the cylindrical fixing member **415** while in the extended state.

In this antenna apparatus **400**, a length ($2\times h2+2\times h3$) and a height h1 of the hula hoop antenna **410**, and the variable capacitor **411** serve to improve the matching characteristic. Therefore, the antenna apparatus **400** does not require a separate matching circuit, since a radio signal is fed to the hula hoop antenna **410** via the microstrip line **412**. Further, it is possible to obtain an input impedance of approximately 50 Ω by adjusting the height of the hula hoop antenna **410** or moving a feeding point right and left.

FIG. 6 illustrates a substantially symmetric current distribution of the antenna apparatus **400** in the extended state. For this symmetric current distribution, a radiation pattern on the azimuth plane is measured to be approximately circular. In the retracted stated, the rod antenna **420** is decoupled from the feeding point and only the hula hoop antenna **410** serves as a radiating element.

Referring back to FIGS. 3 to 5, the conductive fixing member **414** is placed at an upper, right corner of the hula hoop antenna **410**, where the current distribution is relatively the lowest compared to other places. That is, the rod antenna **420** is placed at a given position of the hula hoop antenna **410** where the current distribution is relatively low.

FIG. 7 illustrates the variable capacitor **411** according to a first embodiment of the present invention. As illustrated, the variable capacitor **411** is composed of a screwed cylinder **500** and a screw **510** inserted into the screwed cylinder **500**. The capacitance of the variable capacitor **411** can be varied by screwing the screw **510** clockwise or counter-clockwise to move the screw **520** up or down, respectively.

FIG. **8** illustrates the variable capacitor **411** according to a second embodiment of the present invention. As illustrated, the variable capacitor **411** is composed of a printed circuit board **431** having a plurality of patches **520**. Each of the plurality of patches **520** is connected to an adjacent patch by a patch connection line **530**. The capacitance of the variable capacitor **411** can be varied by cutting the patch connection line **530** at desired positions.

FIGS. **9** and **10** illustrate voltage standing wave ratios (VSWRs) of the antenna apparatus **400** in the retracted state and the extended state, respectively.

FIG. **11** illustrates a radiation pattern of the antenna apparatus **400** on an azimuth plane in the retracted state, and FIG. **12** illustrates a radiation pattern of the prior art antenna apparatus **100** (FIG. **2**) on the azimuth plane in the retracted state. For the antenna apparatus **400**, a gain difference between the maximum and minimum gains on the azimuth plane is 9 dB. This is a much lower gain than that of the prior art antenna apparatus **100**. A low gain difference decreases the directivity of the antenna apparatus **400**, thereby improving the communication quality and providing a stable receiving sensitivity.

FIG. **13** illustrates a radiation pattern of the antenna apparatus **400** on an elevation plane in the retracted state, in which the peak gain appears at around 90°. The prior art antenna apparatus has a peak gain at around 140°, as shown by FIG. **14**. Since the current distribution of the hula hoop antenna **410** is substantially symmetrical, the antenna apparatus **400** can maintain the symmetrical radiation pattern even in the retracted state of the antenna apparatus **400**. In addition, since the rod antenna **420** is constructed to have a length $\lambda/2$ in the extended state, the increase in length of the antenna apparatus **400** increases the antenna gain and improves the communication quality.

FIG. **15** illustrates a radiation pattern of the antenna apparatus **400** on the azimuth plane in the extended state in which the gain difference between the maximum and minimum gains is 5 dB. The prior art antenna apparatus has a gain difference of 8 dB, as shown by FIG. **16**, which is higher by 3 dB than the gain difference of the antenna apparatus **400**. FIG. **17** illustrates a radiation pattern of the antenna apparatus **400** on the elevation plane in the extended state in which the peak gain appears at around 0–90°.

In conclusion, the antenna apparatus **400** has a stable receiving sensitivity and non-directivity by securing a symmetrical radiation pattern. When the present antenna apparatus **400** is used in a PCS (Personal Communication Service) band, it is possible to prevent the asymmetry of the radiation pattern, thereby improving the communication quality.

Although an illustrative embodiment of the present invention has been described herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to that precise embodiment, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. An antenna apparatus for a mobile terminal, comprising:

a hula hoop antenna secured to a housing of the mobile terminal;

a conductive line coupling the hula hoop antenna to a transceiver of the mobile terminal;

a conductive fixing member having a through hole and contacting a portion of the hula hoop antenna;

a cylindrical fixing member inserted into the through hole of the conductive fixing member; and

a rod antenna extendable and retractable from and into the housing, said rod antenna movable along a central axis of the cylindrical fixing member.

2. The antenna apparatus according to claim **1**, wherein the hula hoop antenna has a first end connected to a variable capacitor on a printed circuit board of the mobile terminal and a second end connected to a ground plate of the printed circuit board.

3. The antenna apparatus according to claim **1**, wherein the hula hoop antenna is rectangular-shaped.

4. The antenna apparatus according to claim **1**, wherein the rod antenna includes a polyacetal rod.

5. The antenna apparatus according to claim **1**, wherein an outer surface of the rod antenna is coated with a nonconductive material.

6. An antenna apparatus for a mobile terminal, comprising:

a first antenna having a first end connected to a variable capacitor on a printed circuit board of the mobile terminal and a second end connected to a ground plate of the printed circuit board, said first antenna being secured to a housing of the mobile terminal;

a second antenna extendable and retractable from and into the housing;

a conductive line coupling the first antenna to a transceiver of the mobile terminal;

a conductive fixing member having a through hole and contacting a portion of the first antenna; and

a cylindrical fixing member inserted into the through hole of the conductive fixing member, said second antenna passing through a central axis of the cylindrical fixing member for securing the second antenna to the housing.

7. The antenna apparatus according to claim **6**, wherein the first antenna is a hula hoop antenna made from a metal wire.

8. The antenna apparatus according to claim **6**, wherein the conductive fixing member is fixed to the first antenna at a position which causes a substantially low current distribution to be propagated by the antenna.

9. The antenna apparatus according to claim **6**, wherein the second antenna is a rod antenna made of a wire and coated with a nonconductive material to prevent electrical coupling of the second antenna with the first antenna.

10. The antenna apparatus according to claim **6**, wherein the second antenna has a length $\lambda/2$.

11. The antenna apparatus according to claim **6**, wherein the second antenna is sufficiently thick to contact the first antenna in the extended state.

12. The antenna apparatus according to claim **6**, wherein the second antenna is configured to be electrically decoupled from the first antenna when the second antenna is retracted within the housing, wherein only the first antenna serves as a radiating element.

13. The antenna apparatus according to claim **6**, wherein the variable capacitor comprises:

a screwed cylinder; and

a screw inserted into the screwed cylinder, wherein a capacitance of the variable capacitor can be varied by rotating the screw.

14. The antenna apparatus according to claim **6**, wherein the variable capacitor comprises:

a printed circuit board;

a plurality of patches formed on the printed circuit board; and

a patch connection line for connecting the patches, wherein a capacitance of the variable capacitor can be varied by cutting the patch connection line at given positions.

15. The antenna apparatus according to claim **6**, wherein the first and second antenna operate in a PCS (Personal Communication Service) band.

16. The antenna apparatus according to claim **6**, wherein a current distribution propagated by the antenna apparatus on an azimuth plane is substantially symmetrical when the second antenna is retracted within the housing.

17. The antenna apparatus according to claim **6**, wherein a gain difference of the antenna apparatus between maximum and minimum gains on an azimuth plane is approximately 9 dB when the second antenna is retracted within the housing.

18. The antenna apparatus according to claim **6**, wherein a peak gain of the antenna apparatus occurs at approximately 90° on an elevation plane when the second antenna is extended from the housing.

19. The antenna apparatus according to claim **6**, wherein a gain difference of the antenna apparatus between maximum and minimum gains on an azimuth plane is approximately 5 dB when the second antenna is extended from the housing.

20. An antenna apparatus for a mobile terminal, comprising:

a hoop antenna having a rectangular shape secured to a housing of a mobile terminal;

a second antenna being extendable and retractable from and into the housing;

a conductive line coupling the hoop antenna to a transceiver of the mobile terminal;

a conductive fixing member having a through hole and contacting a portion of the hoop antenna; and

a cylindrical fixing member inserted into the through hole of the conductive fixing member and having a bore therethrough configured to allow the second antenna to pass therethrough.

21. The antenna apparatus according to claim **20**, wherein the hoop antenna has a first end connected to a variable capacitor on a printed circuit board of the mobile terminal, and a second end connected to a ground plate of the printed circuit board.

22. The antenna apparatus according to claim **21**, wherein the variable capacitor comprises:

a screwed cylinder; and

a screw inserted into the screwed cylinder, wherein a capacitance of the variable capacitor can be varied by rotating the screw.

23. The antenna apparatus according to claim **21**, wherein the variable capacitor comprises:

a printed circuit board;

a plurality of patches formed on the printed circuit board; and

a patch connection line for connecting the adjacent patches, wherein a capacitance of the variable capacitor can be varied by cutting the patch connection line at a certain position.

24. The antenna apparatus according to claim **20**, wherein the second antenna is a rod antenna having a length $\lambda/2$ and coated with a non conductive material to prevent electrical coupling with the hoop antenna.

25. The antenna apparatus according to claim **20**, wherein the second antenna is electrically decoupled from the hoop antenna when the second antenna is retracted within the housing, wherein only the hoop antenna serves as a radiating element.

26. The antenna apparatus according to claim **20**, wherein an input impedance of the hoop antenna depends on the height thereof.

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